dam

A dam is a barrier built across a water course to hold back or control the water flow. Dams may be classified according to the functions they serve, and in general terms, a dam is either a storage, diversion, or detention dam. Storage dams are constructed to impound water in periods of surplus supply for use in periods of deficient supply. For example, many small dams impound the spring runoff for later use in the summer dry season. In addition, storage dams may provide a WATER SUPPLY, or an improved habitat for fish and wildlife; they may store water for use in hydroelectric power generation, or for IRRIGATION; or they may be units in a flood control project (see FLOODS AND FLOOD CONTROL).

The specific purpose to be served by a storage dam will influence its design and determine the amount of reservoir storage needed. Where multiple purposes are involved--where, for instance, a dam stores water both for power and for irrigation--a reservoir allocation is usually made for each of the separate uses. The volume of storage, in turn, establishes the height and width of the dam.

Diversion dams are ordinarily constructed to provide sufficient water pressure for carrying water into ditches, canals, or other conveyance systems. Such dams, which are generally shorter than storage dams, are used for irrigation developments, and for diversion from a stream to a distant storage reservoir. Detention dams are constructed to minimize the effect of sudden floods and to trap sediment.

Overflow dams are designed to carry water discharge over their crests, and they must be made of materials that will not be eroded by such discharges. Nonoverflow dams are those designed not to be overtopped, and they may include earth and rock in their structure. Often the two types are combined to form a composite structure consisting of, for example, an overflow concrete gravity dam with dikes of earthfill construction.

To prevent a dam from being overtopped, spillway structures are designed to carry off excess water. In earthfill dams, with crests that cannot survive overtopping, spillways are essential and are usually built as separate structures--often a shaft or tunnel adjacent to the dam. With concrete gravity dams, the downstream side of the structure acts as the spillway.

DAM DESIGN AND STRUCTURE

The most common classification of dams is based on the materials used in their structure and on their basic design.

Earthfill Dams

The development of modern excavating, hauling, and compacting equipment for earth materials has made massive earthfill dams economical. The Rogun and Nurek dams in Tajikistan, the world's highest, are earthfill structures. Canada's Syncrude Tailings, which will be the world's most massive when completed, is also an earthfill structure.

Earthfill dams typically have a water-impermeable clay core, and a water cut-off wall from their base to bedrock to prevent underground seepage. During construction, the stream or river must be diverted either through the damsite by means of a conduit, or around it by means of a tunnel.

Earthfill dams require supplementary structures to serve as spillways for discharging water from behind the dam. If sufficient spillway capacity is not provided, an earthfill dam may be damaged or even destroyed by the erosive action of water flowing over its crest. Unless special precautions are taken, such dams are also subject to serious damage or even failure, due to water seepage through or under the dam (see TETON DAM). The rockfill dam, essentially an embankment like the earthfill dam, uses rock instead of earth to provide stability. It has an impervious, watertight membrane, usually an upstream facing of impervious soil, concrete paving, or steel plates; or it may have a thin interior core of impervious soil.

The rockfill dam must also be provided with a spillway of adequate capacity to prevent overtopping. Its foundation is usually rock or compact sand and gravel and is designed to prevent settlement so great that the watertight membrane might rupture.

Concrete Gravity Dams

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The concrete gravity dam is designed to resist the pressure of reservoir water by sheer weight. Its shape differs from that of the earthfill or rockfill dam in that its inward, water-facing side is perpendicular to the water surface; in profile, the dam forms a right-angled triangle. (Earth and rockfill dams usually have long, gradual slopes on both sides.)

Gravity dams are used to hold back large volumes of water and are adapted to sites where there is a sound rock foundation. Until the early 1900s they were constructed of stone, but modern gravity dams are usually concrete.

Concrete Arch Dams

Concrete arch dams are built in narrow, steep-walled canyons, where the canyon walls can take up the thrust exerted by the arch and the pressure of the water. Such dams can be extraordinarily thin. VAIONT DAM is 265 m (828 ft) high, but only 22.7 m (75 ft) thick at its base. For comparison, HOOVER DAM is 221 m (726 ft) high and 201 m (660 ft) thick at its base. Hoover Dam has a partial arch effect, and is sometimes termed a gravity-arch dam.

Concrete buttress dams are composed of multiple arches reinforced with buttresses. They are usually relatively low dams, built on solid rock beds across a wide river valley. Concrete is saved by using steel buttresses to support the series of smaller concrete arches.

Auxiliary Structures

In addition to the spillway, most dams incorporate several other structures designed to hold or release water. The reservoir, the water-holding area created by the dam, is regulated according to the dam's primary function. For irrigation purposes the reservoir may be filled during spring floods and the water held until the summer, when it is released to irrigate growing crops. The reservoir water level of a flood-control dam is kept low to conserve capacity for floodwaters. To generate hydroelectric power, reservoirs are kept as full as possible, and many power dams use an auxiliary reservoir downstream, from which water can be pumped back to the higher reservoir for additional water power.

Water is drawn out of the reservoir through gate openings in the dam face. The most usual gate form is one that can be raised vertically; more recent gate types use floating roller-caissons that move up and down to control the water flow.

Since a dam effectively blocks the passage of fish, many dams construct stepped pools which allow fish to bypass the dam. A series of fish locks, like the canal locks used for ship passage, may also be used to permit fish to pass both upstream and downstream.

HISTORY

Early agricultural civilizations based in river valleys built dams to control flooding and to provide water for irrigation. The Greek historian Herodotus mentions a dam built across the Nile River about 2900 BC, to protect the city of Memphis from inundation. A rock-fill structure on the Orontes River in Syria, built about 1300 BC, still functions to irrigate fields near the city of Homs. Desert peoples often constructed dams across narrow, dry stream channels, or wadis, to conserve the product of brief, intense rainstorms. The remains of many ancient dams are found throughout the Middle East, along with traces of such other water-retaining structures as tanks and stone cisterns. The Romans built dams throughout their empire. Two Roman dams are still in use in Spain; both have concrete cores with stone facings on the upstream sides and earthfill buttresses.

Dam construction became a lost art in Europe in the centuries after the end of the Roman Empire. It was reborn as a science in the 19th century. In particular, the mid-century studies of soil mechanics by Scottish engineer W. J. M. Rankine allowed the erection of dams whose height no longer needed to be matched by their bulk in order to withstand stress. The French Furens Dam (1861-66) is generally cited as the first dam built on the basis of modern engineering principles. It was a stone masonry structure, curved in cross section, standing 52 m (164 ft) high. French civil engineers contributed greatly to dam design, building structures that were thinner, more elegant, stronger, and more stable than previous dams.

THE DAM-BUILDING ERA

The first years of the 20th century saw many large dams built in both Europe and the United States. In the United States the Federal Reclamation Act of 1902 opened an unprecedented period of dam building. The act established

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the Reclamation Service (now the Bureau of Reclamation) and authorized the building of irrigation projects in the 16 states west of the Mississippi River. (Texas was added in 1906.) The construction of dams to impound water for irrigation was followed, in the 1930s, by projects of much greater scope that were intended to affect whole river basins. The Boulder Canyon Project on the Colorado River, for example--with the HOOVER DAM as its major structure--was designed with multiple purposes: irrigation, power production, flood control, municipal water supply, and recreation are among the most important. The dams built under the TENNESSEE VALLEY AUTHORITY in the 1930s provide other notable examples of multiuse structures functioning to control river waters over a broad region.

There are some 50,000 dams presently operating in the United States. With the exception of two unfinished undertakings, however--the Central Arizona Project and the Central Utah Project--few large dams are planned for the future. Having completed its great work, which was to bring water to the dry lands of the West, the Bureau of Reclamation now sees its role as maintaining the dams it has already built; replacing depleted groundwater supplies that have been pumped into reservoirs; clearing out silt from behind dams; and working with irrigation specialists to solve salinity and other leaching problems. (See HYDROELECTRIC POWER for a review of the environmental effects of large-dam construction.)

Much of the rest of the world, however, continues to build dams. Almost one new dam exceeding 15 m (50 ft) in height is built each day, along with innumerable lesser dams. Large-scale hydroelectric projects offer a source of inexpensive power as well as water for irrigation, and stand as monuments to a country's technological ability.

The ASWAN HIGH DAM in Egypt, completed in 1970, is a prominent example of a structure that not only fulfilled ambitious goals of irrigation and power generation but also stoked a sense of national pride. Another example, the ITAIPU DAM on the Parana River between Paraguay and Brazil, is the world's largest hydroelectric complex, with 18 giant turbines generating an ultimate capacity of 12,600 megawatts. Begun in 1975 and completed in 1991, it cost more than $20 billion and the labor of some 30,000 workers.

Turkey's Ataturk Dam will be another of the world's largest when it is finished in the mid-1990s. The Turkish inhabitants of the arid regions around the dam hope that it will bring prosperity; Syria and Iraq, downstream of the dam, fear a cutoff of Euphrates waters should Turkey wish to exercise its muscle. The Sardar Sarovar dam in Gujarat, India, is the first in a proposed 30-dam project on the Narmada River. Local inhabitants and environmentalists are fighting the project, which will flood a large area and destroy innumerable villages. Construction began in 1993 on the gigantic Three Gorges Dam project on the Yangtze River in China. The dam has long been proposed as the most effective means of preventing the devastating floods that the Yangtze area repeatedly suffers. (It could also eventually supply about 15 percent of China's total power supply.) Opponents argue, however, that the dam will have disastrous social and environmental effects.

F. Eugene McJunkin

Bibliography: Goldsmith, E., and Hildyard, N., The Social and Environmental Effects of Large Dams (1986); Jackson, Donald, Great American Bridges and Dams (1987); Rassweiler, A. D., The Generation of Power: The History of Dneprostnoi (1988); Thukral, E. G., ed., Big Dams, Displaced People (1992).

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